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Social and Ecological Resilience Across the Landscape - SERAL (56500)

Draft Soils Resource Report

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1. Introduction

This report contains the specialist review of soil resource conditions in the Social and Ecological Resilience Across the Landscape (SERAL) project area, which is centrally located on the Stanislaus National Forest, within the Yosemite Stanislaus Solutions (YSS) collaborative area, with portions located on the Calaveras, Mi-Wok, and Summit Ranger Districts. The SERAL project area is located south and east of the North Fork Stanislaus River and north and west of the North Fork Tuolumne River. The project area is also almost entirely to the north and west of Highway 108.

The Social and Ecological Resilience Across the Landscape (SERAL) project is a planning effort designed to restore forest resilience and the landscape's ability to persist with fire as a natural process on the Stanislaus National Forest. Five purpose and need statements were developed for the SERAL project area:

- Increase Landscape Resilience to Natural Disturbances (drought, insects, disease, wildfire) by Restoring Resilient Forest Conditions as Guided by the Natural Range of Variation
- Provide Economic Opportunities to Local Communities
- Maintain Safe Access to Public Lands
- Reduce the Spread of Invasive Non-Native Weeds.

1.01 Proposed Action Summary

The proposed actions are intended to work towards the desired conditions and needs within the project area. Three action alternatives are being analyzed to work towards the desired resource conditions. Table 1.01-1 includes a summary of proposed treatments for action alternatives.

Table 1.01-1 Comparison of Alternatives by Proposed Action

<table>
<tr><th colspan="2">Proposed Activity</th><th>Alternative 1</th><th>Alternative 3: Current Forest Plan</th><th>Alternative 4: Suggested Alternative Variants</th></tr>
<tr><td colspan="2">Forest Thinning: Harvest</td><td>26,728 acres</td><td>11,680 acres</td><td>2,550 acres</td></tr>
<tr><td colspan="2">Forest Thinning: Other Mechanical</td><td>3,770 acres</td><td>14,791 acres</td><td>22,864 acres</td></tr>
<tr><td colspan="2">Mechanical Fuel Reduction</td><td>7,437 acres</td><td>7,460 acres</td><td>7,448 acres</td></tr>
<tr><td colspan="2">Prescribed Fire Only</td><td>19,755 acres</td><td>20,946 acres</td><td>21,226 acres</td></tr>
<tr><td colspan="2">Shaded Fuelbreaks</td><td>13,430 acres</td><td>Same as Alt. 1</td><td>Same as Alt. 1</td></tr>
<tr><td colspan="2">Total Veg Management</td><td>71,121 acres</td><td>68,307 acres</td><td>67,518 acres</td></tr>
<tr><td rowspan="2">Salvage for NRV-based Restoration and Conservation Benefits</td><td>Insect-, Disease-, or Drought-Killed Trees</td><td>37,243 acres</td><td>Same as Alt 1.</td><td>None</td></tr>
<tr><td>Wildfire-Killed Trees</td><td>X acres</td><td>X acres</td><td>None</td></tr>
<tr><td colspan="2">Hazard Tree Removal</td><td>9,939 acres</td><td>X acres</td><td>None</td></tr>
<tr><td colspan="2">Temporary Road Construction</td><td>X miles</td><td>X miles</td><td>X miles</td></tr>
<tr><td colspan="2">Invasive Weed Control and Eradication</td><td>X acres</td><td>Same as Alt. 1</td><td>No herbicides, otherwise same as Alt. 1</td></tr>
<tr><td colspan="2">Forest Plan Amendments</td><td>DEIS Appendix B, Table B.1</td><td>None</td><td>None</td></tr>
</table>

1.02 MANAGEMENT REQUIREMENTS

Soil Requirements common to all action alternatives

1) Follow Forest Service Manual 2550 Soil Management R5 Supplement (USDA, 2017a) and Forest Plan Direction (USDA, 2017b) to identify Soil Management Practices (SMPs) that minimize soil impacts.
    a) Limit skidding with rubber-tired or fixed track equipment to slopes less than 35%; limit low ground pressure tracked equipment (e.g., traditional masticator or feller buncher) to less than 45%; and limit heel-boom loaders / shovel yarding to less than 40% unless otherwise approved by a soil scientist. Dozer piling less than 25%. Mulching mastication treatment less than 35% slope
    b) Tethered logging, or skyline hybrid: Consult soil scientist during unit layout to determine need for Site-specific requirements. May be needed if Erosion Hazard Ratings are predicted to be higher than moderate, or displacement hazard is high in more than one third of a treatment unit (Map 1).
    c) Mulching-type mastication is prohibited on shallow soils, less than 20 inches deep. Appendix Map 2 shows where shallow soils are most likely to occur.
    d) Subsoil or decompact all landings and temporary roads to a depth of 24 inches, and all skid trails to a depth of 18 inches once no longer in use. Exceptions can be made in areas with high rock content; steep slope; moisture content; depth to restricting layer and/or erosion hazards would limit subsoiling feasibility.
    e) On slopes less than 25%, maintain a well-distributed soil cover of 50% (except in fire salvage, maintain existing or increase cover if it is less than 50% before operations begin). Maintain 60% cover on steeper slopes. Soil cover consists of unburned duff and needle fall, basal live plant cover, fine woody debris, and downed logs.
    f) Monitor ground-based operations occurring between October 15 and May 15 (test for soil moisture and trafficability) to prevent soil compaction. Ground-based equipment will operate on relatively dry soils of high soil strength, or bearing capacity.
        i) Wet weather recommendations: Equipment may operate on designated skid trails when soils are dry to a minimum of 4 inches. Low-ground pressure equipment may operate off of designated skid trails when soils are dry to a depth of 4 inches. High-ground pressure equipment may operate off of designated skid trails when soils are dry to a depth of 8 inches.
    g) Install waterbars on hand and dozer lines following waterbar spacing guidelines, Table 1.02-1 below. Location of High and very high EHR shown in Appendix Map 1.

Soil Requirements for Alternative 1 and 3

1) Fire Salvage and post-fire Hazard Tree Abatement
    a) In high erosion hazard areas (Appendix Map 1): On main skidtrails with gradient steeper than 15 percent, apply organic mulch cover (slash, weed-free straw mulch, etc.) to the skid trail footprint and waterbar outlets. Achieve at least 50 percent cover on skidtrail footprint
    b) If soil cover is less than 50% before operations begin, maintain existing or increase well-distributed soil cover.
    c) Subsoil or decompact all landings and temporary roads to a depth of 24 inches except where high rock content, slope, moisture content, depth to restricting layer, and erosion hazard would limit subsoiling feasibility (skid trail subsoiling requirement waived in fire salvage).

Soil Requirements for Alternative 4

This alternative only includes management requirements common to all action alternatives.

Table 1.02-1 Spacing requirements for waterbars o firelines

Fireline Gradient (%)	Waterbar Spacing (ft) by Erosion Hazard Rating			
	Low	Moderate	High	Very High
1-6	400	350	300	250
7-9	300	250	200	150
10-14	200	175	150	125
15-20	150	120	90	60
21-40	90	70	50	30
41-60	50	40	25	15

2. Affected Environment and Environmental Consequences

2.01 FRAMEWORK

Analysis Framework: Statute, Regulation, Forest Plan and Other Direction

National Forest Management Act (NFMA) of 1976 as amended and the Forest and Rangeland Renewable Resources Planning Act of 1974) require the maintenance of productivity and protection of the land and, where appropriate, the improvement of the quality of soil and water resources. NFMA specifies that substantial and permanent impairment of productivity must be avoided.

Forest Service Manual (FSM) 2550 (USDA 2010) establishes the management framework for sustaining soil quality and hydrologic function while providing goods and services outlined in the Forest Plan. Primary objectives of this framework are to inform managers of the effects of land management activities on soil quality and to determine if adjustments to activities and practices are necessary to sustain and restore soil quality. Soil quality analysis and monitoring processes are used to determine if soil quality conditions and objectives have been achieved.

Pacific Southwest Region (Region 5) FSM 2500 Chapter 2550 Supplement (USDA 2017a) establishes soil functions (support for plant growth (productivity) function, soil hydrologic function, and filtering and buffering function) that the Region uses to assess soil conditions and determine if the national soil quality objectives are being met. Each soil function has a set of indicators that frame the desired condition for soil resources. The analysis standards are used for areas dedicated to growing vegetation. They are not applied to lands with other dedicated uses, such as system roads and trails or developed campgrounds.

Effects Analysis Methodology

Soil effects are determined and predicted based on a review of relevant literature and from monitoring reports and observations of soils where similar actions have occurred in the past. While the physical actions may be similar, the impact to soils depends on the soil properties at that location, which can be highly variable. The analysis area for this report consists of soil that supports vegetation growth within the project area boundary. Soils under roads, trails, and recreation sites are not directly considered when addressing soil impacts from the project, but their indirect effects on soils supporting vegetation are considered where necessary (e.g. runoff from roads that leads to erosion in a treatment unit).

The soil effects analysis is bounded in time by the foreseeable future period during which detectable effects on the soil resource could persist in this project area. Some soil features, such as ground cover, can recover quite quickly. Effects on other features, such as compaction and soil organic matter, can persist for decades or centuries. Because soil effects can be persistent, the current soil conditions reflect the cumulative effects of past activities, regardless of when they took place. In general, effects are discussed as short-term (less than 5 years) or long-term effects (longer than 5 years). For cumulative effects, the analysis is bounded in time by past, present and reasonably foreseeable future projects.

Assumptions Specific to Soils

- For soil effects analysis, the baseline condition includes past management actions through August 2020 (when FACTS data was pulled). Actions occurring after that date, but before SERAL implementation begins are considered future foreseeable for the purposes of this report.
- For the purpose of comparing alternatives, the effects of any unplanned wildfire, or large-scale mortality event would be equal between proposed alternatives; the differences would come in what proposed actions occur between the alternatives. Thus, effects of wildfire to soil indicators (direct or indirect) are not discussed and compared between alternatives.
- Assumptions for Erosion Hazard Rating (EHR) analysis are outlined in Nieves-Rivera, 2016. They include:
    - Soil cover inputs to EHR model were estimated from landsat Normalized Difference Vegetation Index (NDVI) values. All slopes are uniform and were generalized by soil type.
    - Ground cover estimates are “current condition” estimates of soil cover and represent the condition of vegetation in the project area when the model was run in 2015. Thus, EHR may be underestimated in the event of a wildfire for salvage and hazard tree proposed actions.
    - Runoff production factor determined from 2-year 6 hour storm events raster.

Data Sources

- Soil survey data including maps and soil properties from the Stanislaus National Forest Soil Survey (USDA 1981).
- Soil interpretations provided by the Region 5 Soil Interpretation Guide (USDA 1999).
- Remote sensing data including the LiDAR DEM.
- Geologic map of Tuolumne county, and associated GIS layers.
- Stanislaus Erosion Hazard Rating (Nieves-Rivera, 2016)

Soils Indicators

The Region 5 supplement (USDA 2017a) to the national soil management chapter provides direction for soil assessment procedures and defines the soil functions and indicators that were used to frame soil condition assessments. Three soil functions (environmental functions of soil) were used for assessment and analysis to determine if the national soil quality objectives were being met: support for plant growth function (soil productivity); soil hydrologic function; and filtering-buffering function. Each of these 3 functions has a set of indicators, listed below, that were used to determine if existing conditions meet the desired soil conditions in the project area.

SOIL STABILITY

- Erosion Hazard Rating
- Amount of soil cover removed by project activities

SURFACE AND SOIL ORGANIC MATTER

- Proportion of treatment types with high displacement hazard.

Soil Strength and Structure

- Area of productivity loss due to compaction or loss of soil porosity
- Area with reduced infiltration due to change in soil structure

Soil Moisture Regime

- Soil moisture regime in meadows and fens is retained

Filtering Buffering Function

- Soil microorganism populations
- Leaching potential of applied herbicides
- Risk of off-site movement of applied herbicides

The indicators above will be used to determine if the three soil functions are in line with soil quality standards. Soil stability refers to a soil's ability to resist erosion. Soil cover protects a soil from water and wind erosion; and slope, vegetation type and infiltration rates all affect the overall risk of erosion. The EHR method incorporates all these factors to show relative differences in soil stability. To preserve soil stability, soil cover should be managed to avoid a high EHR (USDA 1999) after project activities are complete. For surface organic matter, an organic mulch consisting of duff and small woody debris should cover approximately 50% of the soil surface, or more where erosion risk is higher, and 85% of soil organic matter should be preserved in the top 12 inches of soil (USDA 2017b). Soil porosity and soil structure should be maintained similar to the natural condition to maintain a favorable rooting environment for plants and to ensure sufficient infiltration rates to accommodate precipitation inputs (USDA 2012). Soil moisture regimes should not be altered from their natural state, especially in wet meadows and fens (USDA 2017a). Lastly, no specific measures for soil filtering buffering function have been developed. Instead, the Region 5 Soil Management Handbook Amendment (USDA 2017a) states: for projects that involve the application of chemicals, such as herbicides, analyze the effects to soil micro-organisms, post-project erosion risk, leaching potential and risk of off-site movement of the chemicals.

Soil Description and Interpretation

Soils information for this analysis was derived from the Stanislaus National Forest Soil Survey, the NRCS Soil Data Viewer (SDV), and from more detailed soil surveys covering portions of the project area (Norgren et al. 1990). The SDV was used to review distribution of specific soil properties potentially affected by mechanical equipment operations on a unit-by-unit basis. Specific interpretations and soil data properties from the SDV include soil texture, depth, rock content, displacement and erosion hazard, soil taxonomy, soil water holding capacity, and slope percent. The analysis of these data was used, partly, to determine where certain activity types would pose a greater risk to soil productivity.

Soil Erosion Hazard Rating

The Region 5 Soil EHR System (USDA 1999) uses various physical soil properties along with climate and site-specific conditions to rate sheet and rill erosion soil hazards. The method is intended as a site-specific analysis that predicts a soil's risk of erosion in its observed condition. In 2016, Nieves-Rivera developed a model to approximate a soil's EHR based on known soil properties, and remote sensing data (method described in Nieves-Rivera 2016). The product shows where a high EHR is most likely to occur, or the locations where a high erosion hazard could be created with treatment if ground cover is insufficient. Thus, it is displaying the risk of EHR, not the actual rating.

2.02 AFFECTED ENVIRONMENT

Soil Properties

The geology within SERAL includes variable metamorphic rocks in foothill formations to the west, volcanic mudflows and conglomerates on most ridge locations, young glaciated granitics in river canyons, and deeply weathered granitic rocks throughout the west central portion of the area. Project area soils logically follow the geology patterns, with old, deeply weathered clay loam soils derived from metamorphic rock in the lower elevations and granitic rock at mid elevations. Thin or poorly developed soils exist on volcanic ridges and canyon walls, while deep, coarse textured soils occur at the higher, glaciated elevations. Table 2.02-1 displays the general soil groups in the project area and the corresponding soil properties used in the analysis. Most soils within the analysis area have surface textures of loam or sandy loam with gravelly texture modifiers, and the most abundant soils are split between clay loam or sandy loam subsurface textures. This indicates soils with high natural infiltration rates at the surface, but only moderate permeability or ability to transmit water below ground. Specific dominant soils include Josephine, Lithic Xerumbrepts, Holland and Fiddletown. Some soils have a severe compaction rating (high probability to be compacted by activities when moist). These also tend to be the most productive soils in the project area, particularly the Holland and Josephine soils.

Table 2.02-1 Soil Families and Associated Properties Used in Analysis

Family	MAE (%)	T-FAC	Surface Texture	Subsurface Texture	Depth (inches)	COMP Hazard	Rock (%)	DISP Haz
Dystric Lithic Xerochrepts	2.4	1	Cobbly loam	Cobbly loam	10-20	Moderate	10-50	Low
Fiddletown	11	2	Gravelly-Bouldery sandy loam	Gravelly sandy loam	20-60	Slight	35-60	Low
Gerle	5.8	4	Sandy loam	Gravelly sandy loam	40-60+	Slight	5-30	Mod-High
Holland	7.5	4	Loam	Clay loam	40-80+	Severe	5-20	Low
Holland, Dark Surface (Cohasset)	7.5	2-4	Loam	Clay Loam	30-60	Moderate-Severe	5-30	Low
Inville	3	4	Gravelly loam	Gravelly clay loam	20-60	Moderate-Severe	35-50	Low
Josephine	16.5	4	Gravelly loam	Clay loam	20-60+	Severe	10-30	Low
Lithic Xerumbrepts	17	1	Loamy sand	Sandy loam	0-20	Slight	10-50	Low-Mod
McCarthy	10	2-3	Gravelly sandy loam	Sandy loam	20-60	Slight	35-60	Low
Rock Outcrop	2	1	Unweathered bedrock	NA	0-10	Slight		Low
Wilder	4	4	Sandy loam	Sandy loam	40-80+	Slight	0-30	High
Windy	2.7	3	Gravelly sandy loam	Sandy loam	20-60	Slight	10-60	Mod-High
Wintoner	8.6	4	Gravelly loam	Clay loam	40-60+	Severe	0-30	Low

MAE= Maximum Activity Extent (% of total acres); **T-FAC**= Erosion T-Factor; **COMP**= Compaction; **Rock**= Rock Content

Existing Conditions

The project area occurs north and west of Highway 108, a location on the Stanislaus that has relatively little recent fire history, except the Ruby, Darby, and Knight fires. The history of vegetation management is highly variable, especially comparing the eastern and western halves of the project area. Around and to the west of Pinecrest, there is a very long and active history of veg management projects. Fuel treatments, commercial and precommercial thinning, and prescribed fire has covered most of the eastern half of the project area in the past, with some locations along major roadways having entries for vegetation management 10 times or more. The remaining, majority of the project area has fewer than 2 veg management entries or the only action taken has been prescribed fire. This leads to a variety of soil conditions. Where no management history has occurred, and fire suppression has excluded fires, surface organic (and fuel loadings) exceed historic, desired conditions. On the other hand, where management has been intensive, especially in plantations, there is a noticeable impact on soil resources and soil indicators. The plantations, mostly within the Ruby fire and NE part of the project area, show obvious signs of disturbance in soil; altered and thinner than normal surface organic horizons, compaction, and changes in infiltration capacity.

Legacy, or historic evidence of soil disturbance can be seen in the LiDAR hillshade in these locations via a visible skid trail footprint. This is not a perfect indicator of the severity of soil compaction, but it does show with relative accuracy the surface displacement of organic layers, and overall level of impact (in percent area disturbed). Once topsoil displaced or removed through piling or on skid trails, SOM takes a very long time to recover. The number of mechanical treatment entries is shown on Appendix map 3, and the area (acres) with multiple veg management entries is shown in Table 2.02-2.

Table 2.02-2 Summary of Existing Condition of Indicators

# of Entries	Acres	% project area
1	21,500.40	56%
2	7,464.63	20%
3	3,703.97	10%
4	2,162.76	6%
5	1,247.40	3%
>=6	2,088.43	5%

2.03 Environmental Consequences

In the DEIS, effects analysis are framed by Issue. However, most of the issues do not relate directly to environmental consequences of soil resources, so the analysis in this report is organized the soil functions required to be addressed by the Regional Supplement (USDA 2017a), and then by proposed action category. There are various types of proposed activity types in this project that are performed with mechanical equipment or prescribed burning that have similar effects on soil: Forest Thinning: Harvest, Shaded Fuelbreaks, Hazard Tree Removal, and Insect-, Disease-, or Drought-Killed salvage for NRV based restoration. The activities occur in different parts of the landscape but are all performed with mechanical equipment and have similar effects to soil resources; thus, they are all addressed together. Effects from Mechanical fuel reduction, Forest Thinning: Other Mechanical, prescribed fire, Wildfire salvage, temporary road construction, and Invasive Weed Control and Eradication are discussed separately where appropriate.

Alternative 1

Direct and Indirect Effects

Soil Stability

In forest thinning treatments with material removal (forest thinning, hazard tree removal, and insect-, disease, or drought-killed salvage), soil cover would be reduced, especially on landings and main skid trails. In past monitoring of thinning-only treatments in a similar environmental setting, total soil cover typically remained high enough to meet forest standards and prevent a high EHR (McComb and

Westmoreland 2006). Where these thinning treatments also have prescribed understory burning implemented, there would be an additional short-term reduction in soil cover due to organic horizon combustion. However, with typical spring or fall burning and associated high fuel moistures, this reduction would still likely be within forest soil quality guidelines for cover.

Other Mechanical thinning, Fuelbreak treatments, and actions that treat fuels without removal of material or skidding (in other words, treatments done with feller bunchers, mastication, or grapple piling) would have effects similar to those of thinning alone, but after treatment soil cover is typically higher because there is no skid trail network or landings created. Mastication treatments would increase soil cover through additions of shredded tree and shrub material. Burning of any piles created would reduce soil cover immediately under the piles, but the area would likely be small relative to the unit size.

Mechanical treatments on fuelbreaks should be similar to those described above, except where dozer piling is used to push material into piles for burning. Dozer piling is not intended to reduce the fine fuels and litter layers in contact with the ground, but because of “sweeping” of the surface by the larger targeted material, some surface cover would be displaced to piles. Recent and past monitoring of dozer piling shows that it can reduce soil cover well below forest standards in the short term, making sites more susceptible to erosion, but the result is highly dependent on vegetation type and ground cover. In one monitored tractor pile unit, a young plantation burned in the Rim Fire, ground cover averaged only 36% post-treatment. But two other units with a heavy component of manzanita (one burned, and one unburned) both had ground cover above 60% after treatment.

Herbicide applications targeting invasive weed species would create an initial pulse of ground cover as dead vegetation falls to the ground. While some of the invasive weed species provide ground cover for soil stabilization, they can also out-compete a diverse range of native vegetation that may produce better quality ground cover for soil stabilization. Less vegetative cover would be present 1 to 3 years after treatment, but if native species reestablish, the benefits for soil stability would outweigh the temporary reduction in vegetative cover. Manual pulling or grubbing weeds in Alternative 1 is expected to occur in small areas, having minimal effects on soil cover and stability.

Post-fire salvage, and post-fire hazard tree removal could occur in limited situations as described in the DEIS. Though the location and timing of these treatments are not known now, we are able to predict the scale and severity of likely effects from the map of areas these treatments could occur in the DEIS map package, and from past experience on the Stanislaus after the Rim and Donnell fires. In most cases, hazard tree and salvage logging reduce soil cover on landings and skid trails, but actually increase ground cover somewhat in the remainder of treated units (increased compared to high and moderate post-fire condition). This cover is typically large to medium-sized branches that break off as the trees are felled. Monitoring after the Rim fire showed erosion occurred most often on skid trails, or where surface water was concentrated. In high burn areas with low existing ground cover, skid trails with the highest erosion risk would have cover added (management requirements). Wagenbrenner et al. (2015) indicate adding slash to skid trails after salvage logging may reduce erosion from the skid trail footprint; and local observations showed this treatment is most effective when cover quality and ground contact are high. Appendix Map 1 shows the high erosion hazard areas where the skid trail slash management requirement would apply.

Surface and Soil Organic Matter

Surface organic matter refers to organic material on top of the mineral soil surface, including coarse woody debris (CWD), fine wood, and forest floor layers (O soil horizon). This material (especially finer sizes) is important for nutrient cycling and support of soil microorganisms. Soil organic matter (SOM) refers to organic matter that is a component of mineral soil horizons (mainly A horizons). In soils without high clay content, most nutrient exchange occurs in surface soil horizons where SOM is highest. Because of this, it is important to protect SOM, especially on soils with thin A horizons, such as Dystric Lithic Xerochrepts and other shallow soils listed in Table 2.02-1.

Thinning units would generally have surface organic matter redistributed, but not moved off site. The O horizon would be displaced and mixed in areas where feller bunchers walk and on light skid trails. On heavy skid trails, surface organic matter would be buried and mixed in with surface soil horizons and would be scraped away close to landings. In approximately 1,500 acres, aerial logging methods are proposed, where displacement is more likely due to steeper slopes. Thus, soils with high displacement hazard on this treatment type require field review by the soil scientist before implementing. Displacement results in the removal of nutrient rich loamy material, exposing the subsurface which is deficient in soil nutrients, reduces infiltration, and has higher natural soil strength impeding root penetration. Fox et al. (1989) found displacement caused by windrowing decreased forest productivity. Displacement can also lead to channelized flow from entrainment between berms, reduced infiltration, and reduced surface roughness.

Prescribed burning done after thinning (or alone) would reduce surface organic matter through combustion, but relatively moist fuels in spring or fall burns should prevent large continuous losses of surface organic matter. This combination of activities would likely cause a reduction in, or possibly a neutral effect on, total nutrient pools in the forest floor. Many remaining nutrients, especially nitrogen, would mineralize or be released into mineral soil and would be more available to plants and soil biota (Moghaddas and Stephens 2007; St. John and Rundel 1976). Areas with high soil burn severity would result in a net loss of SOM as a result of combustion and volatilization of nutrients. This higher loss of SOM is more likely under pile burning, where fuels are concentrated and are expected to create enough heat to combust SOM immediately under piles.

Effects of mechanical treatments done with feller bunchers or grapple piling would have effects similar to those described for thinning treatments. Mastication treatments would cause a direct increase in surface organic material. Masticated material acts as good soil cover, but in the short-term it does not have the same nutrient exchange properties as SOM or forest floor material. In the long-term as masticated material breaks down, it would provide nutrient exchange benefits. Invasive weed eradication treatments would temporarily increase surface organic matter from dead vegetation accumulating on the soil surface, but are not expected to affect SOM levels.

SOIL STRENGTH AND STRUCTURE

Changes in soil porosity can affect water holding capacity, air and water movement, and the ability of roots to penetrate the soil (Alexander and Poff 1985; Williamson and Neilson 2000). Only about 1/3 of proposed activities are taking place on soils with a high compaction hazard (Table 2.02-1). Soil compaction by mechanical equipment would reduce total porosity in thinning, salvage, and hazard tree units where skidding is proposed. Williamson and Neilson (2000) found that most compaction occurs after 3 passes of log-laden equipment. Landings are areas of high compaction because they support skidding equipment, processors, and trucks. The reduction of porosity would be greatest on landings and segments of main skid trails (Janicki 2006; Jimenez 2007).

Effects of mechanical treatments done with feller bunchers, mastication, or grapple piling would have effects similar to those described for thinning treatments. Slight reductions in soil porosity may occur, but should not reduce soil productivity. Hand thinning, prescribed burn activities, and invasive weed treatments would have little to no effect on soil porosity or compaction.

SOIL MOISTURE REGIME

Most proposed treatments (prescribed fire, invasive weed eradication, mechanical fuel treatment) are unlikely to affect soil moisture regime on uplands. Where these treatments occur, soils don’t typically have a hydric, or moisture-dependent, soil moisture regime. Thus, these activities are not discussed for this soil indicator in any of the remaining alternatives.

In some forest thinning: harvest treatments that are adjacent to meadows, cutting of encroaching conifers is allowed, along with removal if it can be done without damaging the meadow surface (equipment is still excluded from wet meadow areas). Removing live trees around meadows would help maintain water-dependent moisture regimes in meadows by reducing water uptake by planted trees in the long-term.

FILTERING BUFFERING FUNCTION

The only actions that could affect filtering-buffering function of soil are herbicide applications. The other treatments are not evaluated for this indicator.

The fate of herbicides in soil is determined by their chemical structure and reactivity or how they interact with the soil environment. Substances that are soluble in water and do not adsorb readily to soil particles or organic matter can be leached through the soil. Such substances have the potential to reach water when precipitation amounts exceed the water infiltration rates of the soil. Substances that are adsorbed (roughly, bonded to) soil particles are mostly degraded in place and resist leaching. Adsorption of chemicals to soil particles depends primarily on soil clay and organic matter content, temperature, and pH.

According to the SERA report (2011a), it is unlikely glyphosate will be harmful to soil microorganisms under field conditions. Other research indicates that glyphosate can harm soil microorganisms under lab conditions, but it is likely to enhance or have no effect on soil microorganisms in field conditions or in soil (Busse et al. 2001; Wardle and Parkinson 1992). From examination of the effects of glyphosate on microorganisms in numerous forest soils throughout northern California, Busse et al. (2001) failed to detect any changes in microbial population size, diversity, or function due to the herbicide applied at the field rate. When applied at concentrations well above the recommended rate, soil microbial growth was stimulated. Additionally, glyphosate does not appear to reduce the beneficial effect of mycorrhizal fungi (Busse et al. 2001; Chakravarty and Chatarpaul 1990). Ratcliff et al. (2006) concluded that glyphosate has a benign effect on both soil bacterial and fungal community structure when applied at the recommended field rate to organisms in their native soil habitat.

Glyphosate tends to readily adsorb to soil particles, and is degraded by microbial action. This gives Glyphosate a relatively low mobility in soil, rarely penetrating below 12 inches depth. Its persistence in soil is typically less than 3 months and can be less depending on the soil conditions (SERA 2011a). Past monitoring on the Groveland Ranger District has showed with typical application rates used for site preparation and release (which covers much larger and contiguous areas than typical invasive weed treatments), glyphosate was not detected in soil after treatment (Griffith 1993).

Relatively little information is available on the toxicity of clopyralid to soil microorganisms. At concentrations of 10 parts per million (ppm) in soil, clopyralid had no effect on nitrification, nitrogen fixation, or degradation of carbonaceous material (SERA 2004). The USFS uses the 10 ppm value as a no observed effect concentration (NOEC) for soil microorganisms. Use rates for invasive weed eradication would be approximately 0.25 lb active ingredient per acre, per year; this is expected to result in concentrations in soil far below the known value for potentially toxic levels for soil organisms.

Clopyralid is degraded primarily by microbes in soils and aquatic sediments. No metabolites accumulate during the degradation process and therefore, no additional contamination of the environment occurs (Pik et al. 1977). The half-life in soil can range from 10 days to 10 months, depending on soil temperature and moisture conditions (SERA 2004). The half-life for clopyralid is expected to be approximately 25 days for soils in areas treated for invasive weeds. Clopyralid does not bind tightly to soil particles, however the potential for leaching or runoff is functionally reduced by the moderate degradation of clopyralid in soil. Recent monitoring on the Groveland Ranger

District showed no evidence of clopyralid entering water after it was sprayed on invasive weeds adjacent to a stream (Peterson 2012a, 2012b).

The half-life of Aminopyralid in a field setting in soil can range from 25 to 74 days. Longer times of persistence (over 300) days have been observed in a laboratory setting where degradation of aminopyralid was the only means of dissipation (SERA 2007). Soil invertebrates, including earthworms, appear to be relatively unaffected by aminopyralid and show no observable effects when exposed to 5,000 milligrams active ingredient per kilogram of soil (SERA 2007). Similarly, soil microorganisms do not have adverse effects observed at concentrations up to 8 milligrams per kilogram of soil. In fact, the only observed effect was an increase in nitrate and total mineral nitrogen on the day aminopyralid was applied (SERA 2007). Because of the application rates for this herbicide are very low, concentrations are expected to be well below the no effect concentrations given for soil microorganisms and invertebrates. Based on the persistence and toxicity information for Aminopyralid, it is not expected to cause any negative effects to soil microorganisms.

Most studies suggest that Triclopyr is unlikely to have a negative impact on soil microorganism function, but results do vary based on species tested. Several studies show some inhibition of soil fungi growth when applied at lab conditions that far exceed field application rates (e.g. 2 to 5 times higher than concentrations expected proposed rates in this project). Other studies show no effect on nitrogen fixation by lichen at 100ppm, and no impact on soil microbial function or community structure at an application rate of 1.2 lb a.e./acre (USDA, 2011b).

The Triclopyr salt formulation (Garlon 3A) has low leaching potential despite the high solubility. The chemical is biodegradable in soil through microbial metabolism, and soil adsorption increases with time. The herbicide solubility also changes with the organic matter content. From a research review, Ganapathy (1997) reported almost no lateral or vertical movement in soil; most was held by the forest litter at the surface.

Of the herbicides proposed for use, Chlorsulfuron has the highest risk of movement by surface erosion if applied to soils with high clay content or that are shallow and unproductive. This risk is reduced if applied where soils have good surface cover. Chlorsulfuron degrades mostly by water, but persists in soil (SERA 2016). Of the clay influenced soils, most occur in the western 1/3 of the project area within the old metasediments. The evidence of chlorsulfuron's effects on soil microbes is very limited, but from what's available, the impacts appear to be minimal at field application rates. For a normal field application rate, the peak concentration in soil would be about 0.026 mg a.i./kg soil. This concentration is below the only definitive toxicity value for 38 chlorsulfuron in microorganisms—i.e., 60 mg a.i./L in a culture media—by a factor of over 2000. A recent study showed no effect on soil microorganisms at soil concentrations of 50mg a.i./kg of soil.

Based on the current SERA risk assessments, and the intended use rates, all the proposed herbicides would have a low risk for adversely impacting the soil biota. Triclopyr has reportedly affected fungal and bacterial strains in soil, but at use rates above ten times the intended rate (SERA 2011b).

Cumulative Effects

The past management history within the SERAL project area is varied. Some areas, especially in the western 1/3 of the project area have no recorded vegetation management in the FACTS database, while other areas have had more than 7 entries of management actions. Map 3 shows the number of entries for vegetation management across the SERAL landscape. This alone is not enough information to predict where there might still be lasting negative effects to soils, such as severe compaction that limits water movement and storage, or organic matter and losses from piling and site preparation. To determine where these effects occur, the severity of soil impacts from past management types are also important. Actions such as dozer piling or windrowing for site preparation before tree planting have lasting effects, because organic layers were removed and on clay-dominated soils, compaction is typically high enough to limit water movement. Clearcut logging impacts more ground area than modern thinning operations simply because the heavy skidder traffic covers a higher percentage of the treated area. In the SERAL project footprint, most of the past actions had a relatively light impact on soil resources, including: pile burning, understory burning, and understory thinning. These treatments account for most of the entries displayed in Map 3, but they have relatively short-term effects, or don't negatively impact a large area within a unit footprint (e.g. hand piling).

Combining the number of entries, and the severity of the past actions, there are approximately 850 acres within SERAL that have had repeat management entries (more than 5), and also had past activities that could have caused a detrimental effect to soil conditions (such as salvage logging and mechanical site preparation). It is these areas that are most likely to have reduced soil productivity currently. Any additional mechanical action on these acres would slow the natural recovery rate of soils, and could cause additional losses in soil productivity.

Looking at the potential additive effects of actions proposed in SERAL, most treatment types are not likely to add additional acres to those in poor condition currently, but there are two scenarios could. It is possible that unplanned wildfire, or large-scale drought and insect mortality followed by salvage and hazard tree logging could move additional acres of soils to poor condition. In the case of wildfire and other mortality salvage, acreage is intentionally limited (as described in DEIS) to reduce salvage effects at the watershed scale, and these actions must be reviewed by the hydrologist in a Cumulative Watershed Effects analysis before being approved. Hazard tree logging may occur without this CWE analysis however, and the area of potential effects are shown in the hazard tree Appendix maps of the DEIS. One area that could see the largest additive effect to soils that, in their current state are highly disturbed, is the plantations in the Ruby fire footprint.

Alternative 2 (No Action)

Direct and Indirect Effects

SOIL STABILITY

Under Alternative 2, no project activities would occur, so there would be no direct effects on the soil resource. Other actions described in previous analysis, such as the Cedar Ridge CE would continue. Invasive weed populations would remain and continue to displace native vegetation. In some cases, such as with non-native annual grasses, this could lead to a long-term reduction in soil stability. Native bunch grasses evolved under the area's historic fire regime, and the soils that formed under these native species are a product of that long-term relationship. Non-native species may cause a long-term reduction in stability of soil, leading to a reduction in soil productivity.

SOIL MOISTURE REGIME

Thinning of live conifers around meadows would not occur under Alternative 2. In a few cases where there is conifer encroachment threatening the moisture regime, this could impact the meadow's available water and moisture regime. In a majority of the project area, however, no actions would take place that affect soil moisture regime and existing conditions would continue to determine available water for soils in water-dependent systems.

FILTERING BUFFERING FUNCTION

No herbicide applications would occur under Alternative 2. Soil microorganism populations would continue to cycle under normal conditions, and there would be no risk of herbicide substances leaching or movement within the project area.

OTHER SOIL INDICATORS (ORGANIC MATTER, SOIL STRENGTH)

Outside areas with existing NEPA, there would be no direct effects on the soil resource. Under current management, natural processes would continue to dominate areas proposed for treatment; changes to soil strength, porosity, and soil organic matter would be dominated by natural processes.

Cumulative Effects

Past and reasonably foreseeable future actions are the same as described in alternative 1. No other cumulative effects would come from Alternative 2.

Alternative 3

Alternative 3 differs from Alternative 1 mostly in DBH limits, and activities allowed in owl PACs and territories. These changes would affect soils when forest thinning harvest treatment change from operations with skidding, to tracked equipment only (such as mastication or grapple piling instead of skidding). There is also a slightly smaller footprint of vegetation management treatments overall. Other changes in Alt. 3, such as DBH limit changes may affect distribution of, but are unlikely to affect the severity of impacts to soil resources.

Direct and Indirect Effects

Forest thinning harvest (including skidding) would occur on 15,048 fewer acres than Alternative 1. These acres would have slightly less bare soil exposed, and less compaction with this treatment compared to Forest thinning: harvest. All shaded fuelbreak, hazard tree, salvage, and invasive weed treatments would be the same as described in Alternative 1. The described effects, and the acres treated would be the same as Alternative 1.

Prescribed burning (where it occurs as the only treatment) would occur over 1,191 additional acres, but it would have the same effects as described in Alternative 1. The meadow prescriptions and effects to soil moisture regime in meadows for Alternative 3 are the same as in Alternative 1.

Cumulative Effects

The actions that are most likely to cause, or add to a poor soil condition are salvage logging, and hazard tree removal after a large-scale die off caused by fire or insects, disease and drought. While the acreage of harvest treatments with skidding is reduced, the footprint of the highest risk treatments could be nearly the same as Alt 1. Thus, the risk of cumulative negative effects to soils is also similar.

Alternative 4

The changes in Alternative 4 affecting soils, when compared to Alternative 1, include: much fewer acres of forest thinning (none in PACs), no salvage treatment, no hazard tree removal, and no herbicide use for invasive weed control.

Direct and Indirect Effects

SOIL STABILITY

The reduction in forest thinning acres, and the elimination of insect and disease salvage and hazard tree treatments would lead to better soil stability due to a smaller skidtrail footprint. The same assumption about the possibility of uncontrolled wildfire exists for all alternatives, but no salvage is proposed in Alt. 4, so concentration of water on skid trails and erosion resulting from project activities would not increase. The direct effects of the fire itself are not considered, but are assumed to be the same between alternatives, if one occurred.

Invasive weed eradication would be done with only manual or mechanical methods. All manual and mechanical methods would reduce ground cover in some way, similar to Alt 1, but they would occur over more acres since chemical treatments would not occur.

OTHER SOIL INDICATORS (ORGANIC MATTER, STRENGTH, SOIL MOISTURE REGIME)

The reduced area of forest thinning would reduce impacts to other soil indicators as well. Soil displacement of organic matter from harvest operations, and compaction on high clay soils would occur over much less acres, due to the different type of equipment performing the work (lack of skidding and yarding). It is likely mastication would occur over much larger footprint, which would increase surface fuel loading, and surface organic matter wherever it occurs in place of harvesting. The prescribed burning as a sole treatment would occur in ~1,400 additional acres, but would have effects similar to those described in Alternative 1. Finally, the area of confer encroachment removal would be much smaller than alternative 1.

FILTERING BUFFERING FUNCTION

No herbicide applications are proposed in Alternative 4, so the effects to soil filtering buffering function would be the same as described in Alternative 2 (no action). Soil microorganism populations would continue to cycle under normal post-fire conditions without the risk of herbicide substances leaching or moving within the project area.

Cumulative Effects

Overall cumulative effect to soil indicators would be less than either alternative 1 or 3, but more than the no action alternative. No salvage or hazard tree removal is proposed, so these impacts would not be added to the existing footprint of poor soil condition described in alternative 1. Less severe impacts from mastication and grapple piling treatments would replace the skidding in Alt 1 over approximately 24,000 acres.

Summary of Effects Analysis across All Alternatives

Table 2.03-1 Summary of soil indicators by alternative

Indicators	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Soil Stability	Most risk of increased erosion; most skidding and salvage logging.	Lowest short-term erosion risk.	Similar to alt 1, but lower erosion risk where skidding changed to other mechanical.	Erosion risk elevated above alt 2 where skidding occurs; lower than alt 1 or 3.
Surface and SOM	Reduced surface organics from skidding and SOM in steep slope mechanical operations.	Existing OM processes continue	Similar to Alt 1, but fewer acres of steep slope & skidding. More surface OM increase from mastication.	Biggest increase in surface organic matter from possible mastication treatments.
Soil Strength and Structure	Most potential for compaction.	Existing compaction levels persist	Less compaction risk than Alt 1, more than Alt. 4.	least area of new compaction
Soil Moisture Regime	Slight improvement of soil moisture regime in meadows.	No improvement in soil moisture regime	Same as Alternative 1	Same as Alternative 1, but over less area
Filtering Buffering Function	Minimal affect to soil microorganisms from herbicides low risk of off-site movement of herbicides	No affect to soil microorganisms from herbicides no risk of off-site movement	Same as Alternative 1	Same as Alt. 2

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Appendix A – Maps

The following set of maps show the location of soil risk factors addressed in management requirements, and provide a visualization of past management actions (& likely locations of soil cumulative effects).

DISPLACEMENT HAZARD

Topsoil displacement is most likely to occur on soils with coarse texture, weak surface structure, and low rock contents. Gerle soils, for example, formed on glacial debris or outwash material, and can be very susceptable to displacement. In the stanislaus soil survey data, Displacement "hazard" is given as the Probability of high displacement hazard within a map unit (MU). Since map units always contain more than one soil type, the probability represents how common a given soil type is within that MU. For the SERAL analysis, this probability was converted to a hazard rating of Low, Moderate, and High based on how likely a soil with high displacemnt hazard would occur.

High Hazard: >80% probability
Moderate: >40% but less than 80% probability
Low: <40% probability

THIN SOIL HAZARD

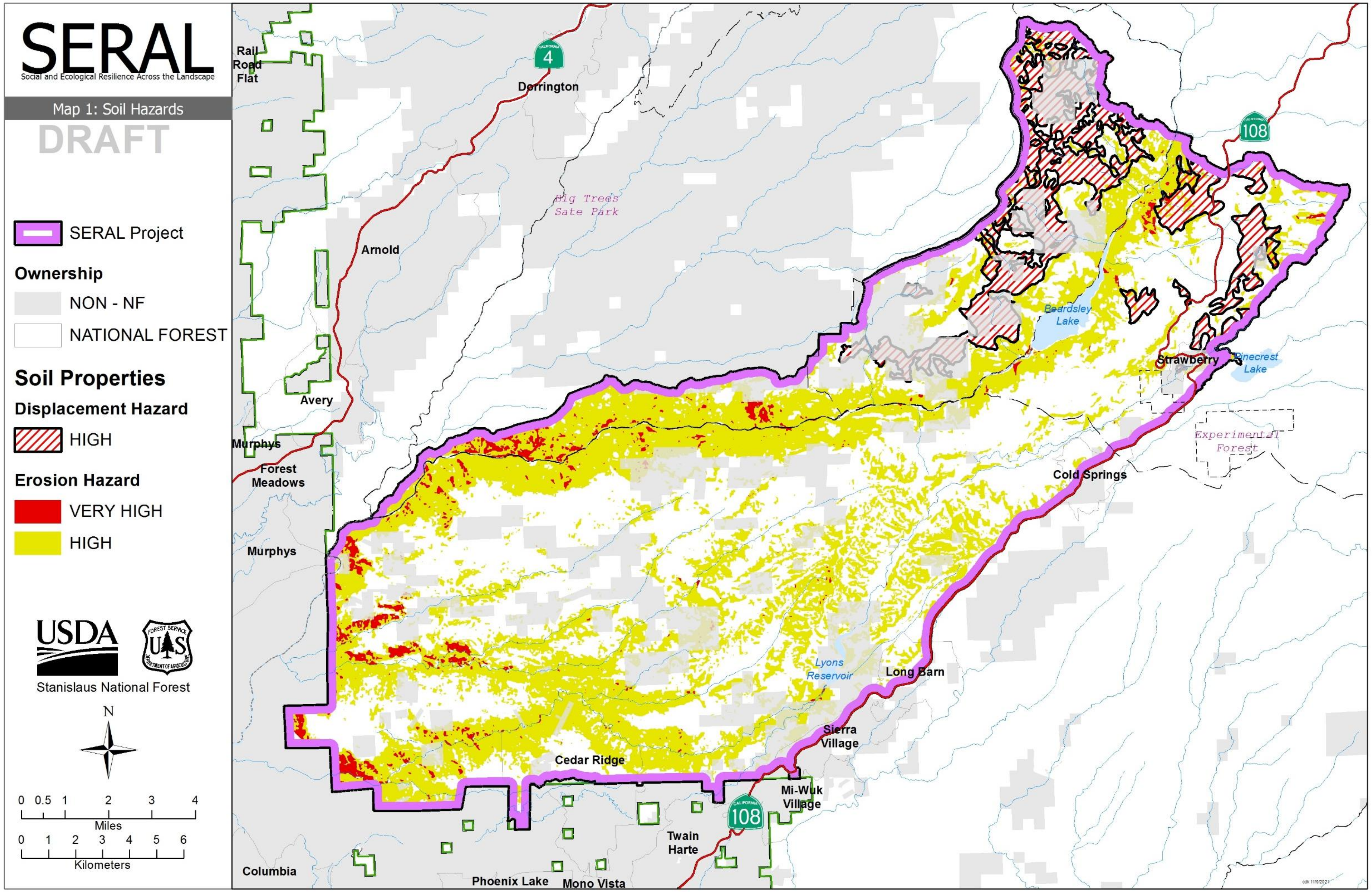
Similar to displacemnt hazard, thin soil "hazard" is displayed in the Stanislaus soil survey as the Probability of a thin soil occuring within a map unit. Since map units always contain more than one soil type, the probability represents how common thin soils are within that map unit classification. For the SERAL analysis, this probability was also converted to a hazard rating of Low, Moderate, and High.

High: >65% probability
Moderate: >40% but less than 65% probability
Low: <40% probability

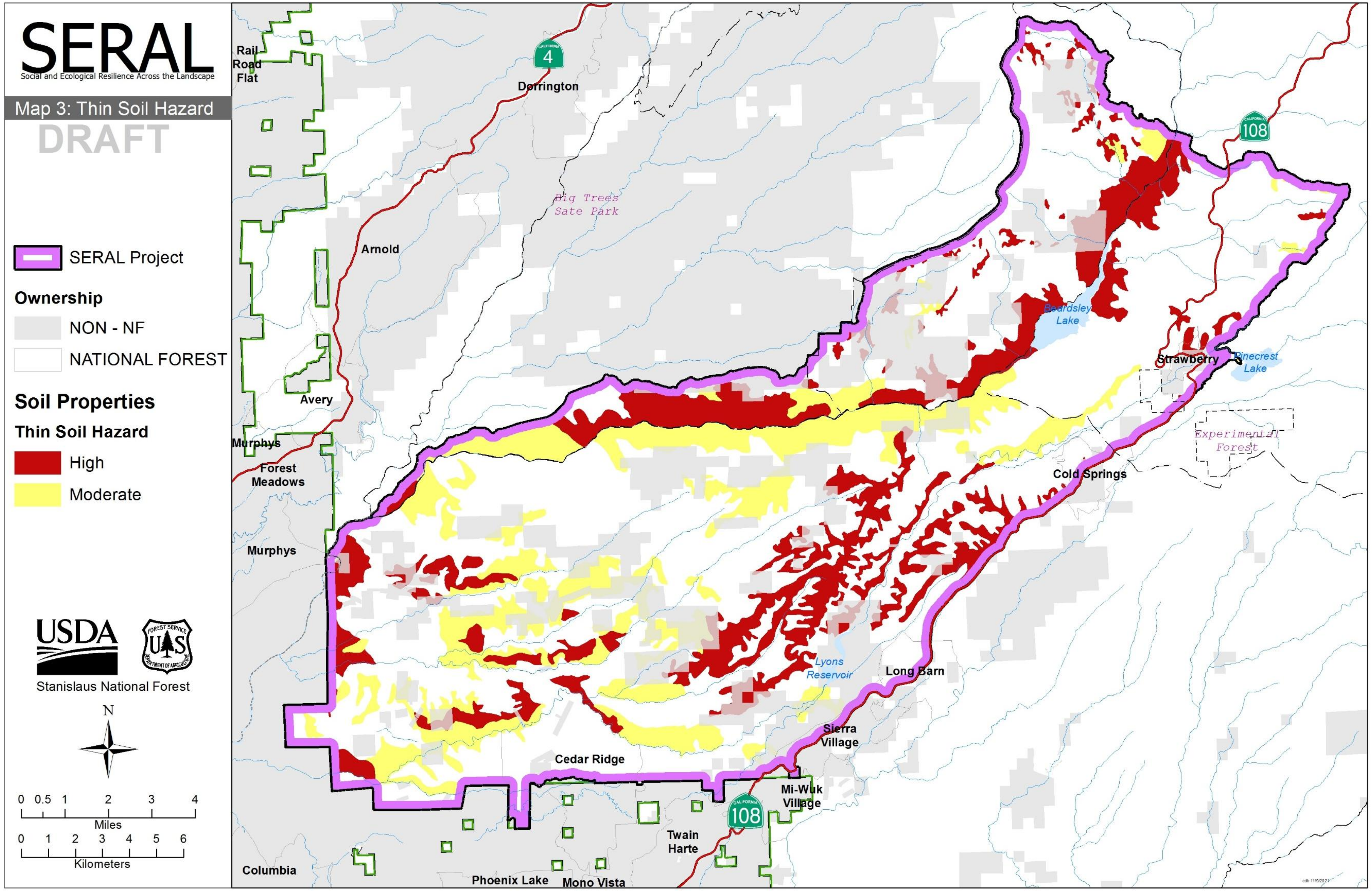
EROSION HAZARD RATING

The method used in this analysis is described in Nieves-Rivera, 2016.

Appendix Map 1 – Soil Hazard map. Displacement and Erosion Hazards.



Appendix Map 2 – Soil Hazard Map. Thin Soils



Appendix Map 3 – Soil Cumulative Effects. # of treatment entries by location